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⑭発明の名称　近赤外域ズームレンズ

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明　細　書

1．発明の名称

近赤外域ズームレンズ

2．特許請求の範囲

1　物体側より順に、合焦のために光軸方向に移動可能な正のパワーをもつ第Ⅰレンズ群と、ズーミングのために光軸方向に移動可能な負のパワーをもつ第Ⅱレンズ群と、ズーミングにより生じる焦点移動を補正するために光軸方向に移動可能な負のパワーをもつ第Ⅲレンズ群と、結像のために固定された正のパワーをもつ第Ⅳレンズ群とから構成されるズームレンズにおいて、

前記第Ⅰレンズ群は、物体側に凸面を向けた負のメニスカス第1レンズと、正の第2レンズと、正の第3レンズと、物体側に凸面を向けた正のメニスカス第4レンズとからなる4群4枚のレンズより構成され、

前記第Ⅱレンズ群は、像側に強い凹面を向けた負の第5レンズと、負の第6レンズと、正の第7レンズとからなり、前記第6，第7レンズを全体として負のパワーをもつ接合レンズとした2群3枚のレンズより構成され、

前記第Ⅲレンズ群は、物体側に強い凹面を向けた負の第8レンズの単レンズより構成され、

レンズ全系のワイド端における焦点距離をf_W，ワイド端における第Ⅰレンズ群から第Ⅲレンズ群までの合成焦点距離を$f_{I,II,III}$，第Ⅰレンズ群の焦点距離をf_I，第Ⅱレンズ群の焦点距離をf_{II}，第iレンズのアッベ数をν_i，物体側より第i番目の面の曲率半径をr_iとするとき、下記の条件（1）～（5）を満足することを特徴とする近赤外域ズームレンズ。

$$(1)\ 1.00 < \left|\frac{f_{I,II,III}}{f_W}\right| < 1.25$$

$$(2)\ 4.20 < \left|\frac{f_I}{f_{II}}\right| < 5.00$$

$$(3)\ 70 < \frac{\nu_2+\nu_3+\nu_4}{3},\ 45 < \frac{\nu_2+\nu_3+\nu_4}{3} - \nu_1$$

$$(4)\ 1.05 < \frac{r_{10}}{f_W} < 1.45$$

$$(1)\ 1.00 < \left|\frac{f_{I,II,III}}{f_W}\right| < 1.25$$

$$(2)\ 4.20 < \left|\frac{f_I}{f_{II}}\right| < 5.00$$

$$(3)\ 70 < \frac{\nu_2+\nu_3+\nu_4}{3},\quad 45 < \frac{\nu_2+\nu_3+\nu_4}{3} - \nu_1$$

$$(4)\ 1.05 < \frac{r_{10}}{f_W} < 1.45$$

$$(5)\ 2.50 < \left|\frac{r_{14}}{f_W}\right| < 3.50$$

の諸条件を満足して構成されることを特徴とする。

更に、本発明は、上述の特徴を有するズームレンズにおいて、前記第Ⅳレンズ群は、物体側より順に、正の第9レンズと両面を凸面とした正の第10レンズと、正の第11レンズと、負の第12レンズと、物体側に凸面を向けた正のメニスカス第13レンズと、物体側に凸面を向けた負のメニスカス第14レンズと、負の第15レンズと、正の第16レンズとからなり、前記第11，第12レンズを全体として正のパワーをもつ接合レンズとし、前記第15，第16レンズを全体として正のパワーをもつ接合レンズとした6群8枚のレンズより構成され、

$$(6)\ \overline{n}_{+} < 1.60,\quad 1.75 < \overline{n}_{-}$$

$$(7)\ 62 < \frac{\nu_9+\nu_{10}+\nu_{11}}{3}$$

の諸条件を満足するよう構成したことを特徴とする。

ここで上記各条件式の符号を次のように定める。

f_W　：レンズ全系のワイド端における焦点距離

$f_{I,II,III}$　：第Ⅰレンズ群から第Ⅲレンズ群までの合成焦点距離

f_I　：第Ⅰレンズ群の焦点距離

f_{II}　：第Ⅱレンズ群の焦点距離

r_i　：物体側より第i番目の面の曲率半径

ν_i　：第iレンズのアッベ数

$\overline{n}_{+}$　：第Ⅳレンズ群中の正レンズのd−lineの平均屈折率

$\overline{n}_{-}$　：第Ⅳレンズ群中の負レンズのd−lineの平均屈折率

「作用」

以下、上記各条件式について説明する。

条件（1）は、第Ⅰレンズ群から第Ⅲレンズ群までのパワーに関するものである。一般に4群ズームレンズの場合は、第Ⅰレンズ群から第Ⅲレンズ群までで大きな負のパワーを有しており、この第Ⅰレンズ群から第Ⅲレンズ群までのパワーを適切に配分することにより、諸収差をバランス良く補正することが可能となる。条件（1）の上限を越えると、各群のパワーがゆるくなり、収差補正上は有利になるが、レンズの全長が大きくなり、小型化という点で好ましくない。逆に下限を越えて第Ⅰレンズ群から第Ⅲレンズ群のパワーが強くなると、同時に第Ⅳレンズ群の正のパワーが増大し、諸収差をバランス良く補正することが困難になる。

条件（2）は、第Ⅰレンズ群と第Ⅱレンズ群の焦点距離の比に関するものであり、変倍時の収差変動を小さくおさえるための条件である。条件（2）の上限を越えると、第Ⅱレンズ群のパワーが強くなり、変倍時に特にコマ収差の変動を小さくおさえることが困難になる。逆に下限を越えると、第Ⅰレンズ群のパワーが強くなり、球面収差を小さくおさえることが困難になる。

条件（3）は、本発明のズームレンズの特徴とする可視領域から近赤外領域の広い波長域において、焦点ズレが少なく良好な像性能を得るために、色収差，球面収差をバランス良く補正するための条件である。条件（3）で第Ⅰレンズ群中の正レンズのアッベ数の平均を70以上に保つことにより、第Ⅰレンズ群中で発生する2次スペクトルの色収差を小さくおさえることが可能となる。さらに、第Ⅰレンズ群中の正レンズのアッベ数の平均と負レンズのアッベ数の差を45以上に保つことにより、各レンズのパワーを分散し、高次の球面収差の発生をおさえることが可能となる。

条件（4）は、第Ⅱレンズ群中の負の単レンズ

25	16.050	1.25	1.80518	25.4
26	11.166	3.30		
27	24.940	1.20	1.77250	49.6
28	10.770	8.00	1.48749	70.2
29	−60.350	1.50		
30	∞	2.80	1.51633	64.1
31	∞			

	f =10.75	f =33.11	f =102.00
d_8	2.45	32.97	48.53
d_{13}	51.91	14.51	5.81
d_{15}	3.00	9.88	3.02

(1) $\left|\dfrac{f_{I\cdot II\cdot III}}{f_V}\right| = 1.028$

(2) $\left|\dfrac{f_I}{f_{II}}\right| = 4.729$

(3) $\dfrac{\nu_2+\nu_3+\nu_4}{3} = 77.8$, $\dfrac{\nu_2+\nu_3+\nu_4}{3} - \nu_1 = 52.4$

(4) $\dfrac{r_{10}}{f_V} = 1.344$

(5) $\left|\dfrac{r_{14}}{f_V}\right| = 2.783$

(6) $\overline{n}_+ = 1.548$, $\overline{n}_- = 1.794$

(7) $\dfrac{\nu_9+\nu_{10}+\nu_{11}}{3} = 77.8$

〔実施例2〕

F_{NO} = 1 : 1.63　f =10.75〜102.00

ω =26.9° 〜3.0°

面No	r	d	n	ν
1	235.918	2.80	1.80518	25.4
2	83.777	2.47		
3	98.038	8.80	1.49700	81.6
4	−828.042	0.20		
5	76.974	9.50	1.49700	81.6
6	2388.211	0.20		
7	52.007	9.80	1.49700	81.6
8	173.557	可変		
9	90.120	1.20	1.77250	49.6
10	12.546	6.90		
11	−33.882	1.20	1.48749	70.2
12	16.135	5.75	1.80518	25.4
13	96.360	可変		
14	−28.496	2.00	1.48749	70.2
15	810.001	可変		
16	92.112	4.80	1.48749	70.2
17	−35.003	0.10		
18	69.323	4.00	1.48749	70.2
19	−106.202	0.10		
20	78.222	8.00	1.48749	70.2
21	−24.227	1.30	1.80518	25.4
22	−76.543	0.10		
23	18.455	3.15	1.77250	49.6
24	28.587	7.55		
25	19.889	1.25	1.80518	25.4
26	12.032	2.73		
27	20.961	1.20	1.77250	49.6
28	12.925	5.80	1.48749	70.2
29	−61.688	1.50		
30	∞	2.80	1.51633	64.1
31	∞			

	f =10.75	f =33.11	f =102.00
d_8	2.00	30.91	45.56
d_{13}	45.91	11.92	6.07
d_{15}	6.70	11.79	2.99

(1) $\left|\dfrac{f_{I\cdot II\cdot III}}{f_V}\right| = 1.105$

(2) $\left|\dfrac{f_I}{f_{II}}\right| = 4.493$

(3) $\dfrac{\nu_2+\nu_3+\nu_4}{3} = 81.6$, $\dfrac{\nu_2+\nu_3+\nu_4}{3} - \nu_1 = 56.2$

(4) $\dfrac{r_{10}}{f_V} = 1.167$

(5) $\left|\dfrac{r_{14}}{f_V}\right| = 2.651$

(6) $\overline{n}_+ = 1.544$, $\overline{n}_- = 1.794$

(7) $\dfrac{\nu_9+\nu_{10}+\nu_{11}}{3} = 70.2$

〔実施例3〕

F_{NO} = 1 : 1.63　f =10.75〜102.00

ω =27.2° 〜3.0°

面No	r	d	n	ν
1	141.419	2.80	1.80518	25.4
2	75.216	3.50		
3	120.767	6.80	1.49700	81.6
4	2011.979	0.20		
5	78.987	9.00	1.49700	81.6
6	454.362	0.20		
7	56.022	11.40	1.49700	81.6
8	668.714	可変		
9	156.874	1.20	1.76200	40.1
10	13.184	6.70		
11	−32.563	1.20	1.48749	70.2
12	16.956	5.20	1.80518	25.4
13	105.763	可変		
14	−35.729	2.00	1.48749	70.2
15	−1474.000	可変		
16	111.574	5.40	1.49700	81.6
17	−31.599	0.10		
18	40.502	4.20	1.49700	81.6
19	−126.364	0.10		
20	−1137.265	6.70	1.48749	70.2
21	−22.471	1.30	1.80518	25.4
22	−696.345	0.10		
23	22.733	3.50	1.80518	25.4
24	72.590	8.70		

差図である。

I：第Ｉレンズ群

II：第IIレンズ群

III：第IIIレンズ群

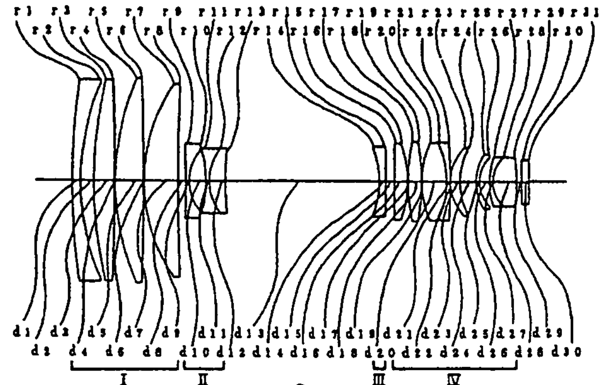
IV：第IVレンズ群

特許出願人　旭光学工業株式会社

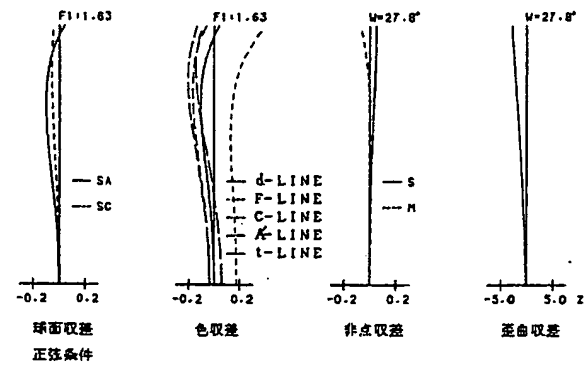
代表者　松本　徹

同代理人　弁理士　伊丹　辰男

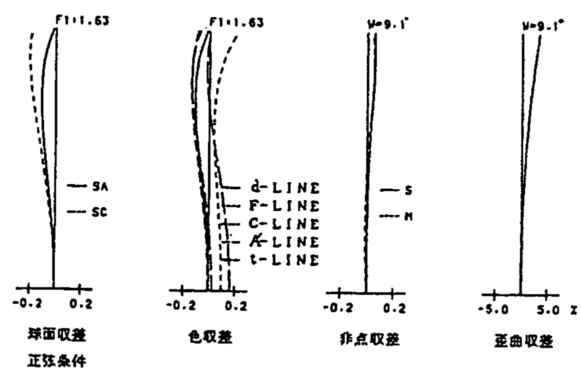
第1図



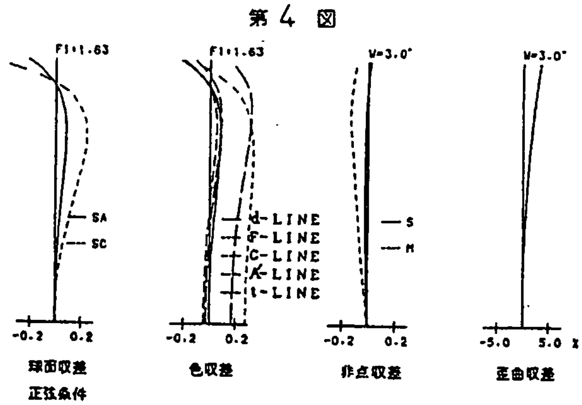
第2図



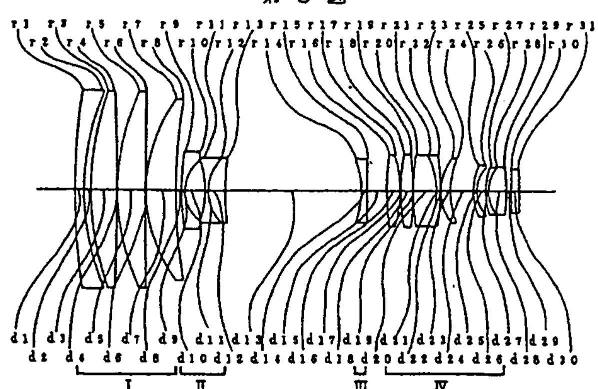
第3図



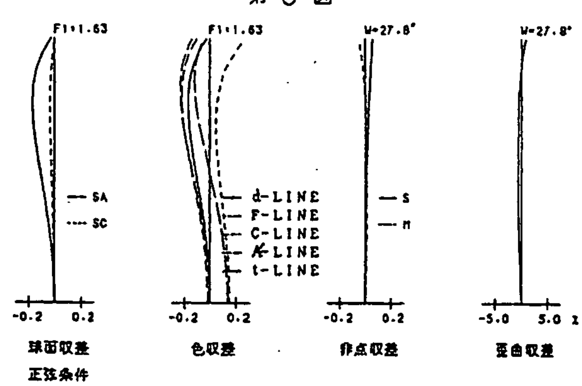
第4図



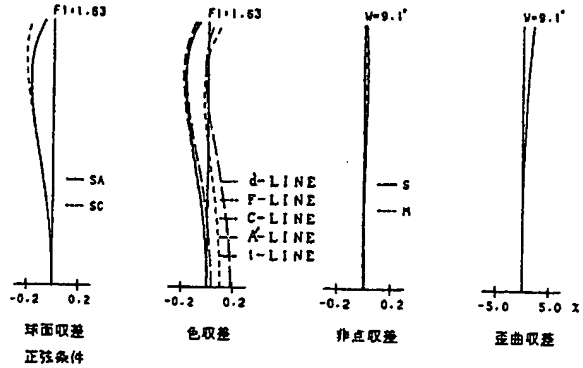
第5図



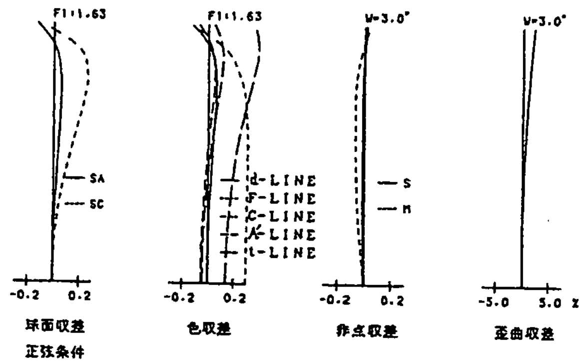
第6図



第15図


F1:1.63
SA
SC
-0.2 0.2
球面収差
正弦条件
F1:1.63
d-LINE
F-LINE
C-LINE
t-LINE
-0.2 0.2
色収差
W=9.1°
S
M
-0.2 0.2
非点収差
W=9.1°
-5.0 5.0 %
歪曲収差

第16図


F1:1.63
SA
SC
-0.2 0.2
球面収差
正弦条件
F1:1.63
d-LINE
F-LINE
C-LINE
t-LINE
-0.2 0.2
色収差
W=3.0°
S
M
-0.2 0.2
非点収差
W=3.0°
-5.0 5.0 %
歪曲収差

Date: September 15, 2005

Declaration

I, Michihiko Matsuba, President of Fukuyama Sangyo Honyaku Center, Ltd., of 16-3, 2-chome, Nogami-cho, Fukuyama, Japan, do solemnly and sincerely declare that I understand well both the Japanese and English languages and that the attached document in English is a full and faithful translation of the copy of Japanese Unexamined Patent No. Hei-2-126213 laid open on May 15, 1990.

Michihiko Matsuba

Fukuyama Sangyo Honyaku Center, Ltd.

NEAR-INFRARED REGION ZOOM LENS

Japanese Unexamined Patent No. Hei-2-126213

Laid-open on: May 15, 1990

Application No. Sho-63-280981

Filed on: November 7, 1988

Inventor: Nobutaka MINEFUJI

Applicant: Asahi Optical Co., Ltd.

Patent Attorney: Tatsuo ITAMI

SPECIFICATION

1. TITLE OF THE INVENTION

NEAR-INFRARED REGION ZOOM LENS

2. WHAT IS CLAIMED IS;

1. A near-infrared region zoom lens comprising, in order from the object side, a first lens group with a positive power that is movable in the optical axis direction for focusing, a second lens group with a negative power that is movable in the optical axis direction for zooming, a third lens group with a negative power that is movable in the optical axis direction for correcting focal point shifting caused by zooming, and a fourth lens group with a positive power fixed for image forming, wherein

the first lens group is composed of four-group four lenses of a negative meniscus first lens having a convex surface turned toward the object side, a positive second lens, a positive third lens, and a positive meniscus fourth lens having a convex surface turned toward the object side,

the second lens group is composed of two-group three lenses of a negative fifth lens having a strong concave surface turned toward the image side, a negative sixth lens, and a positive seventh lens, where the sixth and seventh lenses are formed into a cemented lens having a negative power in total,

the third lens group is composed of a single lens of a negative eighth lens having a strong concave surface turned toward the object side, and

the following conditions (1) through (5):

(1) $$1.00 < \left|\frac{f_{I \cdot II \cdot III}}{f_w}\right| < 1.25$$

(2) $$4.20 < \left|\frac{f_I}{f_{II}}\right| < 5.00$$

(3) $$70 < \frac{\nu_2 + \nu_3 + \nu_4}{3}, \quad 45 < \frac{\nu_2 + \nu_3 + \nu_4}{3} - \nu_1$$

(4) $1.05 < \frac{r_{10}}{f_w} < 1.45$

(5) $2.50 < \left|\frac{r_{14}}{f_w}\right| < 3.50$

are satisfied, provided that the focal length at the wide end of the entire lens system is defined as f_w, the composite focal length of the first lens group through the third lens group at the wide end is defined as $f_{I \cdot II \cdot III}$, the focal length of the first lens group is defined as f_I, the focal length of the second lens group is defined as f_{II}, the Abbe's number of the i-th lens is defined as ν_i, the radius of curvature of the i-th surface from the object side is defined as r_i.

2. The near-infrared region zoom lens according to Claim 1, wherein the fourth lens group is composed of six-group eight lenses of a positive ninth lens, a positive tenth lens having both convex surfaces, a positive eleventh lens, a negative twelfth lens, a positive meniscus thirteenth lens having a convex surface turned toward the object side, a negative meniscus fourteenth lens having a convex surface turned toward the object side, a negative fifteenth lens, and a positive sixteenth lens, where the eleventh and twelfth lenses are formed into a cemented lens with a positive power in total, and the fifteenth and sixteenth lenses are formed into a

cemented lens with a positive power in total, and the following conditions (6) and (7):

(6) $\bar{n}_+ < 1.60$, $1.75 < \bar{n}_-$

(7) $62 < \dfrac{\nu_9 + \nu_{10} + \nu_{11}}{3}$

are satisfied, provided that the average refractive index of the d line of the positive lenses in the fourth lens group is defined as $\bar{n}_+$, the average refractive index of the d line of the negative lenses is defined as $\bar{n}_-$, and the Abbe's number of the i-th lens is defined as ν_i.

3. DETAILED DESCRIPTION OF THE INVENTION

[Field of the Invention]

The present invention relates to a zoom lens to be used in a monitoring camera, etc., and more specifically, a near-infrared region zoom lens that has a brightness of an aperture ratio of approximately 1 : 1.6 and a zooming ratio of approximately 10×, and is compact and realizes excellent performance in a broad waveband from the visible region to the near-infrared region.

[Prior Arts]

Recently, various monitoring cameras have been increasingly used for monitoring of various systems, etc.

Among these monitoring cameras, in particular, a type to

be used for monitoring outdoors day and night is used in the daytime under normal sunlight, that is, light in the visible region, however, it may be used when a monitoring object is illuminated by light in the infrared region at night. As a conventional zoom lens of this type, for example, the inventions of Japanese Patent Publication No. Sho-61-39648 and Japanese Unexamined Patent Publication No. Sho-60-11812 are known.

[Problem to be Solved by the Invention]

However, these inventions are designed on the assumption that they are used within the visible region, so that when they are used under illumination in the infrared region, focal point deviation becomes especially great due to chromatic aberration between the visible region and the infrared region, so that the focal point needs to be corrected. Furthermore, even after correcting the focal point, since the lens is not originally designed by taking the performance in the infrared region into account, when an infrared ray is used for illumination, a satisfactory image cannot be obtained.

The invention was made to solve the above-described problem, and an object thereof is to provide a zoom lens which is compact although its number of lenses is equivalent to that of the invention of Japanese Patent Publication No. Sho-61-39648, and

realizes small chromatic aberration and excellent performance in a broad waveband from the visible region to the infrared region, and has a large aperture and a high zooming ratio.

[Means for Solving the Problem]

In order to achieve the above-described object, the near-infrared region zoom lens of the invention is composed of four lens groups in total including, in order from the object side, a first lens group with a positive power that is movable in the optical axis direction for focusing, a second lens group with a negative power that is movable in the optical axis direction for zooming, a third lens group with a negative power that is movable in the optical axis direction for correcting focal point shifting caused by zooming, and a fourth lens group with a positive power fixed for image forming, wherein

the first lens group is composed of four-group four lenses of, in order from the object side, a negative meniscus first lens having a convex surface turned toward the object side, a positive second lens, a positive third lens, and a positive meniscus fourth lens having a convex surface turned toward the object side,

the second lens group is composed of, in order from the object side, two-group three lenses of a negative fifth lens having a strong concave surface turned toward the image side, a

negative sixth lens, and a positive seventh lens, where the sixth and seventh lenses are formed into a cemented lens having a negative power in total,

the third lens group is composed of a single lens of a negative eighth lens having a strong concave surface turned toward the object side, and

the following conditions (1) through (5):

(1) $1.00 < \left|\frac{f_{I \cdot II \cdot III}}{f_w}\right| < 1.25$

(2) $4.20 < \left|\frac{f_I}{f_{II}}\right| < 5.00$

(3) $70 < \frac{\nu_2 + \nu_3 + \nu_4}{3}$, $45 < \frac{\nu_2 + \nu_3 + \nu_4}{3} - \nu_1$

(4) $1.05 < \frac{r_{10}}{f_w} < 1.45$

(5) $2.50 < \left|\frac{r_{14}}{f_w}\right| < 3.50$

are satisfied.

Furthermore, according to the invention, in the zoom lens having the above-described characteristics, the fourth lens group is composed of six-group eight lenses of, in order from

the object side, a positive ninth lens, a positive tenth lens having both convex surfaces, a positive eleventh lens, a negative twelfth lens, a positive meniscus thirteenth lens having a convex surface turned toward the object side, a negative meniscus fourteenth lens having a convex surface turned toward the object side, a negative fifteenth lens, and a positive sixteenth lens, where the eleventh and twelfth lenses are formed into a cemented lens with a positive power in total, and the fifteenth and sixteenth lenses are formed into a cemented lens with a positive power in total, and the following conditions (6) and (7):

(6) $\bar{n}_{+} < 1.60 \quad , \quad 1.75 < \bar{n}_{-}$

(7) $62 < \dfrac{\nu_9 + \nu_{10} + \nu_{11}}{3}$

are satisfied.

Herein, the symbols in the conditional expressions are defined as follows:

f_w: focal length at the wide end of the entire lens system

$f_{I \cdot II \cdot III}$: composite focal length of the first lens group through the third lens group

f_I: focal length of the first lens group

f_{II}: focal length of the second lens group

r_i: radius of curvature of the i-th surface from the object

side

ν_i: Abbe's number of the i-th lens

$\overline{n}_+$: average refractive index of the d line of the positive lenses in the fourth lens group

$\overline{n}_-$: average refractive index of the d line of the negative lenses in the fourth lens group

[Action]

Hereinafter, the conditional expressions are described.

The condition (1) relates to the powers of the first lens group through the third lens group. Generally, in the case of a four-group zoom lens, the first lens group through the third lens group have a great negative power, and the powers of the first lens group through the third lens group are properly allocated, whereby aberrations can be corrected in a balanced manner. If the upper limit of the condition (1) is exceeded, the powers of the respective groups are lowered, and this is preferable for correcting chromatic aberration, however, this is not preferable in terms of compactness since it results in an increase in the entire lens length. To the contrary, if the lower limit is exceeded and the power of the first lens group through the third lens group becomes strong, the positive power of the fourth lens group simultaneously increases and it becomes difficult to correct aberrations in a balanced manner.

The condition (2) relates to a focal length ratio of the first lens group and the second lens group, and is a condition for reducing aberration fluctuations when zooming. If the upper limit of the condition (2) is exceeded, the power of the second lens group becomes strong, and it becomes difficult to reduce fluctuations of, in particular, coma aberration when zooming. To the contrary, if the lower limit is exceeded, the power of the first lens group becomes strong, and it becomes difficult to reduce spherical aberration.

The condition (3) is for correcting chromatic aberration and spherical aberration in a balanced manner in order to obtain smaller focal point deviation and excellent image performance in a broad waveband from the visible region to the near-infrared region as a feature of the zoom lens of the invention. By keeping the average Abbe's number of the positive lenses in the first lens group at 70 or more by the condition (3), second-order spectral chromatic aberration occurring in the first lens group can be reduced to be small. Furthermore, by keeping the difference between the average Abbe's number of the positive lenses and the Abbe's number of the negative lens in the first lens group at 45 or more, the powers of the lenses can be dispersed and occurrence of high-order spherical aberration can be restrained.

The condition (4) relates to the radius of curvature of the strong concave surface on the image side of the negative single lens (the fifth lens) in the second lens group, and is a condition for excellently correcting distortion aberration and spherical aberration. If the radius of curvature r_{10} increases over the upper limit of the condition (4), the fluctuation of distortion aberration according to zooming increases, and this is not preferable. To the contrary, if the radius of curvature r_{10} becomes smaller than the lower limit, it becomes difficult to restrain the fluctuation of spherical aberration.

The condition (5) relates to the radius of curvature of the surface on the object side of the negative single lens (the eighth lens) of the third lens group. The third lens group corrects focal point shifting caused by zooming, and by reducing the radius of curvature of the negative single lens to the range of the condition (5), without deterioration of aberrations excellently corrected by the first and second lens groups, the aberration fluctuations according to zooming can be reduced to be small. If the upper limit of the condition (5) is exceeded, it becomes difficult to correct the fluctuation of coma aberration when zooming in a balanced manner, and to the contrary, if the lower limit is exceeded,

it becomes difficult to reduce spherical aberration and curvature of field to be small.

The condition (6) relates to the refractive indexes of the positive lenses and the negative lenses in the fourth lens group, and is a condition for excellently correcting the Petzval sum of the entire system and reducing the curvature of field and astigmatism to be small. In a four-group zoom lens, since the first lens group through the third lens group have a strong negative power, the Petzval sum of the entire lens system takes a negative value, and the curvature of field tends to be excessively corrected. Therefore, in the fourth lens group, within the range of the condition (6), the refractive indexes of the negative lenses are set to be high, and the refractive indexes of the positive lenses are set to be low, whereby the Petzval sum of the entire lens system can be set to be positive, and it becomes possible to correct curvature of field and astigmatism in a balanced manner.

The condition (7) relates to the average of the Abbe's numbers of the positive lenses (the ninth, tenth, and eleventh lenses) arranged first, second, and third from the object side in the fourth lens group, and is a condition for reducing the chromatic aberration of magnification occurring in the fourth lens group to be small. In the four-group zoom lens, a light

flux to be made incident on the fourth lens group is a divergent light flux, and this is imaged at a predetermined image magnification and a desired focal length is obtained. The positive lenses close to the object side in the fourth lens group gently refract the incident divergent light flux with almost no lowering of the incidence height and turns the divergent light flux into a state close to a parallel pencil, and at this point, by keeping the average of the Abbe's numbers of the positive lenses close to the object side at 62 or more, occurrence of chromatic aberration of magnification can be minimized.

[Example]

Numerical data of examples of the invention are shown below. F_{NO} denotes the aperture ratio, f denotes the focal length of the entire lens system, ω denotes the half angle of view, r denotes the radius of curvature of each lens surface, d denotes the lens thickness or the lens distance, n denotes the refractive index of the d line of each lens, and ν denotes the Abbe's number of each lens.

In the numerical data of the examples, the plane-parallel plate arranged on the extremely image surface side is a filter, faceplate, etc., to be used in a video camera, etc.

[Example 1]

F_{NO}= 1:1.63 f= 10.75 - 102.00

ω= 27.8° - 3.0°

Surface No.	r	d	n	ν
1	217.200	2.80	1.80518	25.4
2	80.000	4.60		
3	142.500	7.00	1.48749	70.2
4	-993.485	0.20		
5	84.000	9.50	1.49700	81.6
6	-1208.500	0.20		
7	55.963	11.50	1.49700	81.6
8	762.000	Variable		
9	-480.000	1.20	1.77250	49.6
10	14.449	5.78		
11	-38.388	1.20	1.48749	70.2
12	17.040	5.50	1.80518	25.4
13	89.769	Variable		
14	-29.920	2.00	1.48749	70.2
15	-1520.979	Variable		
16	-912.000	4.40	1.49700	81.6
17	-35.389	0.10		
18	71.000	4.40	1.49700	81.6
19	-71.000	0.10		
20	33.299	8.00	1.48749	70.2
21	-33.299	1.25	1.80518	25.4
22	-208.250	0.10		
23	16.408	3.15	1.77250	49.6
24	22.350	5.23		
25	16.050	1.25	1.80518	25.4
26	11.166	3.30		
27	24.940	1.20	1.77250	49.6
28	10.770	8.00	1.48749	70.2
29	-60.350	1.50		
30	∞	2.80	1.51633	64.1
31	∞			

	f= 10.75	f= 33.11	f= 102.00
d_8	2.45	32.97	48.53
d_{13}	51.91	14.51	5.81
d_{15}	3.00	9.88	3.02

(1) $\left|\frac{f_{I \cdot II \cdot III}}{f_w}\right| = 1.028$

(2) $\left|\frac{f_I}{f_{II}}\right| = 4.729$

(3) $\frac{\nu_2 + \nu_3 + \nu_4}{3} = 77.8$, $\frac{\nu_2 + \nu_3 + \nu_4}{3} - \nu_1 = 52.4$

(4) $\frac{r_{10}}{f_w} = 1.344$

(5) $\left|\frac{r_{14}}{f_w}\right| = 2.783$

(6) $\bar{n}_+ = 1.548$, $\bar{n}_- = 1.794$

(7) $\frac{\nu_9 + \nu_{10} + \nu_{11}}{3} = 77.8$

[Example 2]

F_{NO} = 1:1.63 f= 10.75 - 102.00

ω= 26.9° - 3.0°

Surface No.	r	d	n	ν
1	235.918	2.80	1.80518	25.4
2	83.777	2.47		
3	98.038	8.80	1.49700	81.6
4	-828.042	0.20		
5	76.974	9.50	1.49700	81.6
6	2388.211	0.20		
7	52.007	9.80	1.49700	81.6
8	173.557	Variable		
9	90.120	1.20	1.77250	49.6

10	12.546	6.90		
11	-33.882	1.20	1.48749	70.2
12	16.135	5.75	1.80518	25.4
13	96.360	Variable		
14	-28.496	2.00	1.48749	70.2
15	810.001	Variable		
16	92.112	4.80	1.48749	70.2
17	-35.003	0.10		
18	69.323	4.00	1.48749	70.2
19	-106.202	0.10		
20	78.222	8.00	1.48749	70.2
21	-24.227	1.30	1.80518	25.4
22	-76.543	0.10		
23	18.455	3.15	1.77250	49.6
24	28.587	7.55		
25	19.889	1.25	1.80518	25.4
26	12.032	2.73		
27	20.961	1.20	1.77250	49.6
28	12.925	5.80	1.48749	70.2
29	-61.688	1.50		
30	∞	2.80	1.51633	64.1
31	∞			

	f= 10.75	f= 33.11	f= 102.00
d_8	2.00	30.91	45.56
d_{13}	45.91	11.92	6.07
d_{15}	6.70	11.79	2.99

(1) $\left|\frac{f_{I\cdot II\cdot III}}{f_w}\right| = 1.105$

(2) $\left|\frac{f_I}{f_{II}}\right| = 4.493$

(3) $\frac{\nu_2 + \nu_3 + \nu_4}{3} = 81.6$, $\frac{\nu_2 + \nu_3 + \nu_4}{3} - \nu_1 = 56.2$

(4) $\frac{r_{10}}{f_w} = 1.167$

(5) $\left|\frac{r_{14}}{f_w}\right| = 2.651$

(6) $\bar{n}_+ = 1.544$, $\bar{n}_- = 1.794$

(7) $\frac{\nu_9 + \nu_{10} + \nu_{11}}{3} = 70.2$

[Example 3]

F_{NO} = 1:1.63 f= 10.75 - 102.00

ω= 27.2° - 3.0°

Surface No.	r	d	n	ν
1	141.419	2.80	1.80518	25.4
2	75.216	3.50		
3	120.767	6.80	1.49700	81.6
4	2011.979	0.20		
5	78.987	9.00	1.49700	81.6
6	454.362	0.20		
7	56.022	11.40	1.49700	81.6
8	668.714	Variable		
9	156.874	1.20	1.76200	40.1
10	13.184	6.70		
11	-32.563	1.20	1.48749	70.2
12	16.956	5.20	1.80518	25.4
13	105.763	Variable		
14	-35.729	2.00	1.48749	70.2
15	-1474.000	Variable		
16	111.574	5.40	1.49700	81.6
17	-31.599	0.10		
18	40.502	4.20	1.49700	81.6
19	-126.364	0.10		
20	-1137.265	6.70	1.48749	70.2
21	-22.471	1.30	1.80518	25.4
22	-696.345	0.10		
23	22.733	3.50	1.80518	25.4
24	72.590	8.70		

25	18.622	1.25	1.80518	25.4
26	11.687	2.25		
27	21.544	1.20	1.80518	25.4
28	13.760	5.90	1.48749	70.2
29	-51.816	1.50		
30	∞	2.80	1.51633	64.1
31	∞			

	f= 10.75	f= 33.11	f= 102.00
d_8	2.00	32.49	47.84
d_{13}	50.80	11.81	6.50
d_{15}	4.54	13.04	3.00

(1) $\left|\frac{f_{I \cdot II \cdot III}}{f_w}\right| = 1.208$

(2) $\left|\frac{f_I}{f_{II}}\right| = 4.737$

(3) $\frac{\nu_2 + \nu_3 + \nu_4}{3} = 81.6$, $\frac{\nu_2 + \nu_3 + \nu_4}{3} - \nu_1 = 56.2$

(4) $\frac{r_{10}}{f_w} = 1.226$

(5) $\left|\frac{r_{14}}{f_w}\right| = 3.324$

(6) $\bar{n}_+ = 1.555$, $\bar{n}_- = 1.805$

(7) $\frac{\nu_9 + \nu_{10} + \nu_{11}}{3} = 77.8$

[Example 4]

F_{NO} = 1:1.63 f= 10.75 - 102.00

ω= 27.0° - 3.0°

Surface No.	r	d	n	ν
1	287.290	2.80	1.80518	25.4
2	82.169	1.89		
3	88.138	9.50	1.49700	81.6
4	-683.487	0.20		
5	74.366	10.50	1.49700	81.6
6	-2509.042	0.20		
7	52.563	8.00	1.61800	63.4
8	109.582	Variable		
9	72.737	1.20	1.77250	49.6
10	12.349	7.60		
11	-31.949	1.20	1.48749	70.2
12	16.328	5.70	1.80518	25.4
13	96.630	Variable		
14	-29.511	1.80	1.48749	70.2
15	534.409	Variable		
16	75.615	5.00	1.56873	63.1
17	-36.529	0.10		
18	64.509	3.60	1.56873	63.1
19	-133.122	0.10		
20	319.738	8.00	1.48749	70.2
21	-22.762	1.30	1.80518	25.4
22	-111.115	0.10		
23	20.197	3.15	1.77250	49.6
24	36.964	8.02		
25	19.212	1.25	1.80518	25.4
26	12.180	2.58		
27	20.015	1.20	1.77250	49.6
28	13.214	5.68	1.48749	70.2
29	-72.880	1.50		
30	∞	2.80	1.51633	64.1
31	∞			

	f= 10.75	f= 33.11	f= 102.00
d_8	2.32	30.92	45.34
d_{13}	45.15	11.43	6.10
d_{15}	6.96	12.09	3.00

(1) $\left|\frac{f_{I\cdot II\cdot III}}{f_w}\right| = 1.113$

(2) $\left|\frac{f_I}{f_{II}}\right| = 4.473$

(3) $\frac{\nu_2 + \nu_3 + \nu_4}{3} = 75.5$, $\frac{\nu_2 + \nu_3 + \nu_4}{3} - \nu_1 = 50.1$

(4) $\frac{r_{10}}{f_w} = 1.148$

(5) $\left|\frac{r_{14}}{f_w}\right| = 2.745$

(6) $\overline{n}_+ = 1.577$, $\overline{n}_- = 1.794$

(7) $\frac{\nu_9 + \nu_{10} + \nu_{11}}{3} = 65.4$

[Effects of the Invention]

As described above, in comparison with a conventional zoom lens of this type that could not realize satisfactory performance when it is used in the infrared region, the invention provides a zoom lens that has excellent performance in a broad waveband from the visible region to the infrared region, and is structurally compact, and has sufficient great effects for use in a monitoring camera that is used day and night, whereby the object of the invention is sufficiently achieved.

4. BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1, Fig. 5, Fig. 9, and Fig. 13 are lens sectional views of examples 1, 2, 3, and 4 of the invention in order;

Figs. 2, Figs. 6, Figs. 10, and Figs. 14 are aberration diagrams at the wide end of examples 1, 2, 3, and 4 of the invention in order;

Figs. 3, Figs. 7, Figs. 11, and Figs. 15 are aberration diagrams at the middle focal length of examples 1, 2, 3, and 4 of the invention in order; and

Figs. 4, Figs. 8, Figs. 12, and Figs. 16 are aberration diagrams at the tele end of examples 1, 2, 3, and 4 of the invention in order.

I: First lens group

II: Second lens group

III: Third lens group

IV: Fourth lens group

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Patent Attorney: Tatsuo ITAMI

Fig. 2 – Fig. 8, Fig. 10 – Fig. 12, and Fig. 14 – Fig. 16

Spherical aberration / Sine condition

Chromatic aberration

Astigmatism

Distortion aberration

Fig.1

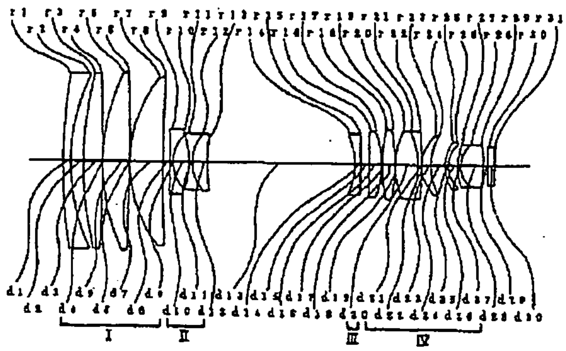


Fig.2

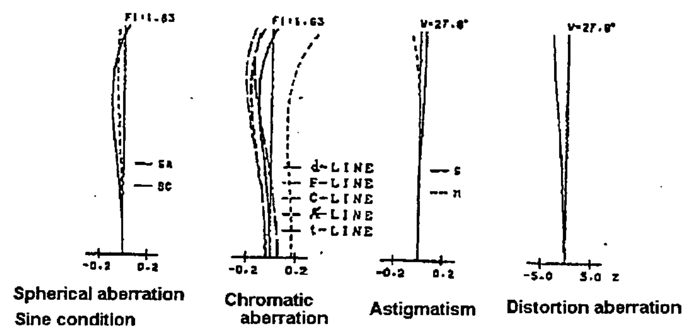


Fig.3

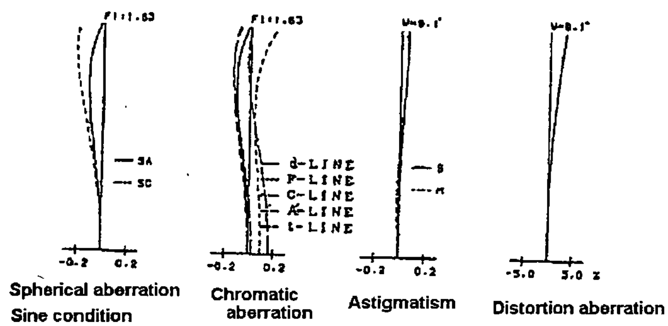


Fig.5

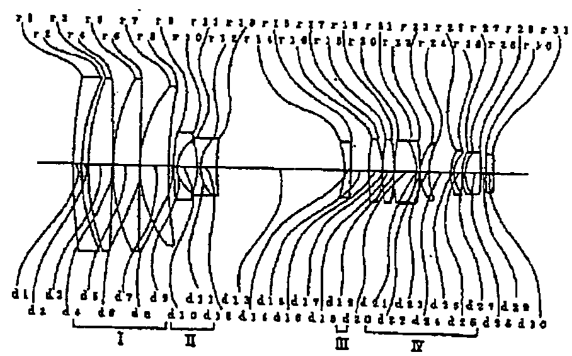


Fig.4

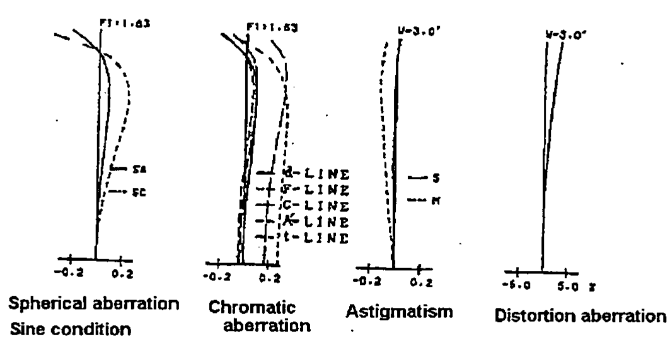


Fig.6

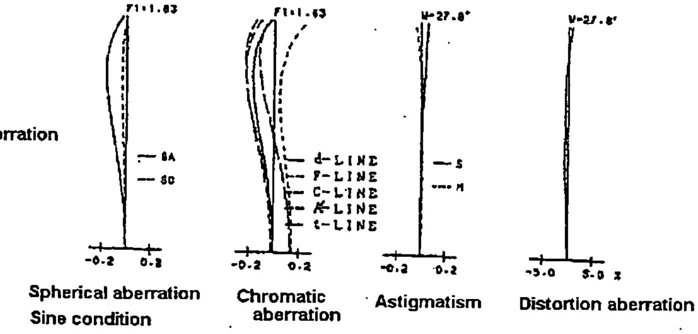


Fig.7

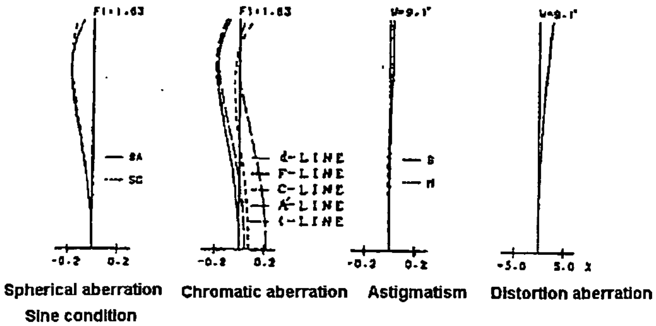


Fig.9

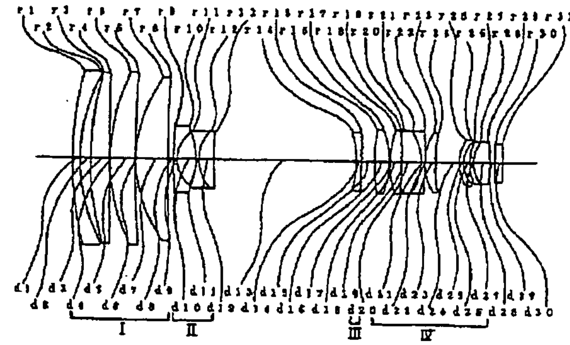


Fig.8

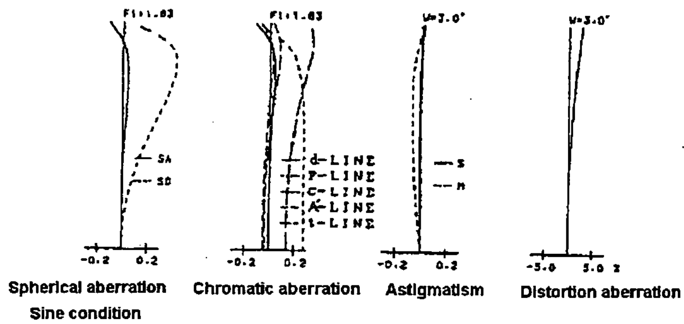


Fig.10

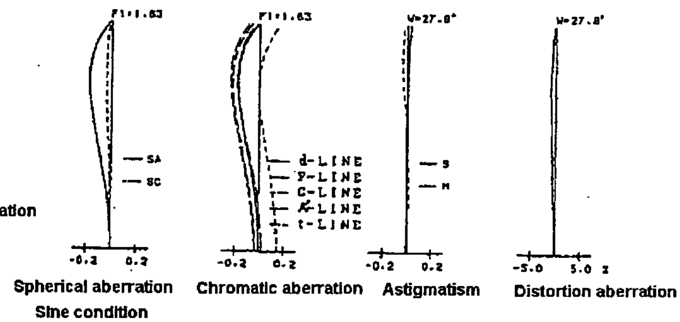


Fig.11

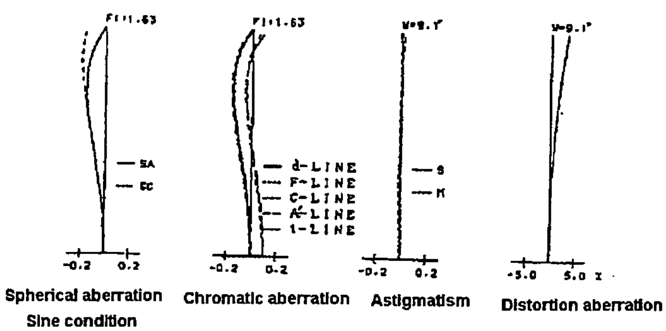


Fig.13

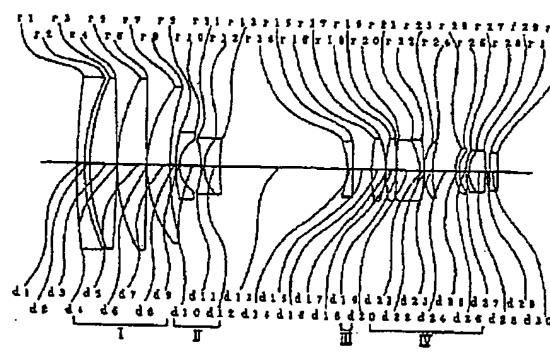


Fig.12

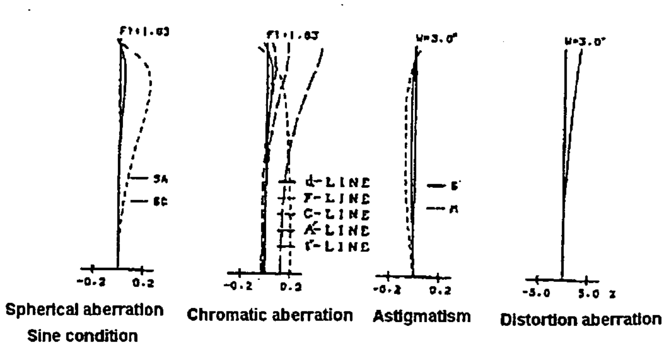


Fig.14

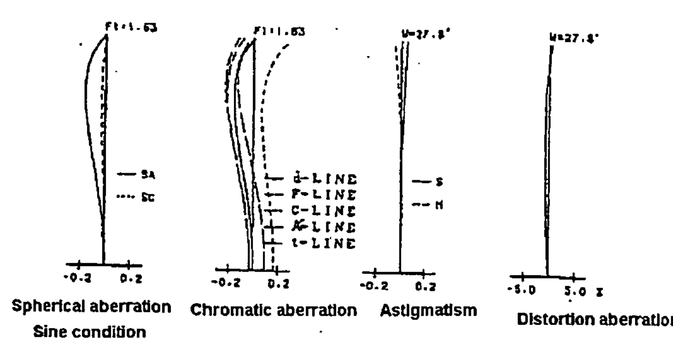
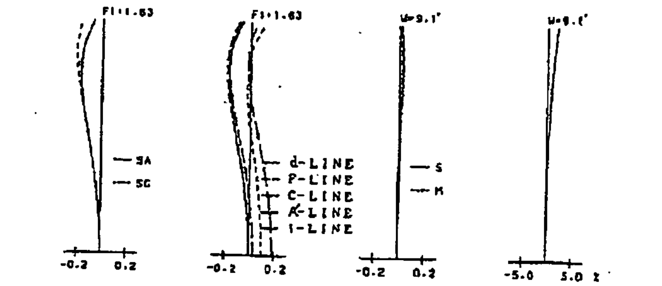
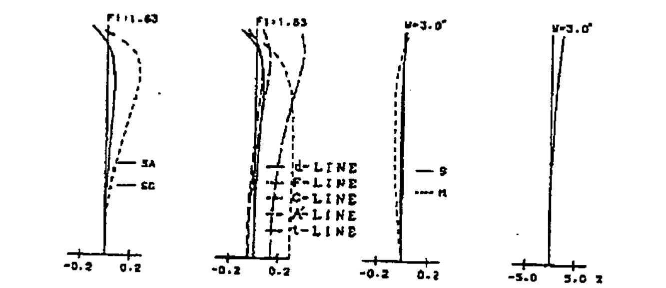


Fig.15



Spherical aberration Sine condition | Chromatic aberration | Astigmatism | Distortion aberration

Fig.16



Spherical aberration Sine condition | Chromatic aberration | Astigmatism | Distortion aberration